Median Related Issues

Monday-August 14, 2000 – 10:00 AM – 11:30 AM
Track 2 - Technical

INDIRECT LEFT TURNS -

THE MICHIGAN EXPERIENCE

By

Herbert S. Levinson
Transportation Consultant, New Haven, CT

F.J. Koepke, SK Consultants

David Geiger, Michigan DOT

Dave Allyn, Oakland County Road Commission

Carmine Palumbo - SE Michigan Council of Governments

Prepared for

4th Annual Access Management Conference
Portland, Oregan

August 13-16, 2000

ABSTRACT

INDIRECT LEFT TURNS – THE MICHIGAN EXPERIENCE

BY

Herbert S. Levinson	Transportation Consultant, New Haven, CT
F.J. Koepke	SK Consultants
David Geiger	Michigan DOT
Dave Allyn	Oakland County Road Commission
Carmine Palumbo	S.E. Michigan Council of Governments

Left turns at intersections have been a recurring problem, especially at suburban intersections. To simplify conflicts, indirect left/U-turns in advance or beyond intersections have been increasingly utilized. The Michigan Department of Transportation has provided U-turn channels on highways with wide-medians and prohibited all left-turns at signalized intersections for many decades. More recently Oakland County, Michigan has installed “U” turns on some of its arterials.

This paper provides an overview and analysis of the Michigan “U”. It describes the origin, features and application of the concept, with a focus on the Detroit metropolitan area – including the more recent applications in Oakland County. It presents the reported safety and operational benefits, and community response. It compares capacities and service levels with those for more conventional facilities.

The paper also gives a case study of Telegraph Road (US-24) in six-to-eight lane roadway carrying up to 100,000 vehicles per day. It describes the signal coordination, traffic flow, and travel times/speeds as well as safety. It also describes the Livernois Road Experience in Oakland County.

Finally, the paper describes the access management implications, and the opportunities for application elsewhere.

INDIRECT LEFT TURNS - THE MICHIGAN EXPERIENCE

Left turns pose problems at driveways and street intersections. They increase conflicts, delays, and crashes, and they complicate traffic signal timing. Therefore, left turns have been given increased attention both in access management plans and roadway design concepts.

The Michigan Department of Transportation (MDOT) has long believed that the best way to improve safety and capacity along wide median divided highways is to prohibit left turns at signalized intersections and to install directional "U Turn" crossovers downstream from the nearby signalized intersections. The crossovers then accommodate the left turns that would otherwise occur at signalized intersections. MDOT has installed these crossovers for more than forty years.

The discussion that follows provides an overview and analysis of these directional median crossovers. It describes the origin, application, and design features, presents the reported safety and operational benefits, and gives some case studies.

BACKGROUND

Several highways in Michigan, particularly in the Detroit area, were constructed with wide medians on wide rights-of-way. Many of these medians are 60 to 100 feet in width and were built in semi-rural areas decades ago to separate opposing directions of traffic and to provide an adequate median width for landscaping and beautification. The wide rights-of-way were originally established for “super highways” as they were called, in the 1920’s. By the early 1960’s many of these highways were experiencing capacity problems, generally because of interlocking left turns within the bi-directional crossovers at the major street intersections. To correct this capacity problem, directional (one-way) crossovers were constructed through the median on the far sides of the intersection of the major crossroads, and the left-turning traffic was required to use the crossovers. The prohibition of left turns at signalized intersections permits two-phase traffic signal control, increases in capacity and improves safety.

Today, there are more than 425 miles of “boulevards” with directional crossovers on the state highway system.(1) Most of these crossovers are found along divided highways in the Detroit Metropolitan Area. The ‘U’ turns have been provided wherever the central median is at least 50-to-60 feet.

Figure 1 shows the extent of the 116 miles of MDOT “boulevards” in Wayne and Oakland Counties in the Detroit Metropolitan Area. Directional ‘U’ turns are found on major arterial roads such as Telegraph Road (US24), Woodward Ave (M-1), Fort Road (M-85), Eight Mile Road (M-102), Grand River Ave (M-5), Michigan Road (US12), Northwestern Highway (M-10), Hall Road (M-59), and M-15. Interchanges have been provided at a few locations where these major highways cross (i.e. 8-Mile Road at Telegraph and Woodward).

Table 1 summarizes 1998 traffic volumes and crash rates for these trunk line highways. Traffic volumes range from about 9,000 vehicles per day (Fort Road) up to 147,000 vehicles per day (Northwestern Highway). The crashes (accidents) when normalized by distance and traffic volumes range from about 1 to 6 accidents per million VMT.

The extent of these indirect left turn lane designs, and the estimated time periods when these lanes were probably installed are as follows.

Table 1

1998 Traffic and Crash Data
State Highways With Indirect Left Turns in the Detroit Area

Route:	Terminus	Terminus	Distance	Low ADT	High ADT	Crashes	Crash/Mi.	Est. Crash Rate/ Million VMT(1)
Wayne County								
M-102/8Mile Road	Grand River	I-94	20.4 Mi.	28,700	82,500	1035	101.4/Mi.	5
M-5/Grand River Ave	Middlebelt Road	Telegraph Rd.	2.9 Mi.	20,500	31,000	165	56.9/Mi.	6
M-85/Fort Road	I-75/Monroe Co.	I-75	14.6 Mi.	8,700	39,900	502	34.4/Mi.	3.8
US-12/Michigan Rd.	Wayne Co. Line	Greenfield Rd.	15.0 Mi.	12,800	49,600	951	63.4/Mi.	5.6
M-1/Woodward Ave	McNichols Road	South Boulevard	16.0 Mi.	19,800	79,900	967	60.4/Mi.	3.4
US-24/Telegraph Rd.	Eureka Road	8 Mile Road	17.5 Mi.	18,300	75,800	1616	92.3/Mi.	5.4
Oakland County								
US-24/Telegraph Rd	8 Mile Road	Orchard Lake Road	13.7 Mi.	56,600	96,000	1411	103.0/Mi.	3.7
M-10/Northwestern	I-696	14 Mile Road	4.0 Mi.	74,800	146,800	905	226.3/Mi.	5.6
M-59	Oakland Co. Line	Porter Road	7.5 Mi.	24,500	31,000	92	12.3/Mi.	1.2

Notes: (1) Based on Average of Low and High ADT

Source: Michigan Department of Transportation

Wayne County

M102 8-Mile Road. This boulevard section is about 20.4 miles and serves as the dividing line between Wayne County and Oakland and Macomb Counties. It extends from Grand River Avenue on the west to I-94 on the east. In 1968, a major improvement was made and lanes were added to increase capacity. This may have been when indirect left turns were introduced and median crossovers were signalized. 1998 daily traffic volumes ranged from 39,000 at the west terminal to 82,500 near the Lodge Freeway (M-101) and decreased to 23,700 on the east terminal near I-94. The approximate crash rate was 5.0 crashes per million VMT.

M-5 Grand River Avenue. This boulevard section extends 2.9 miles from the northwest of Middlebelt Road to the southeast of Telegraph Road. A major improvement was made in 1960. 1988 daily traffic volumes ranged from 20,500 to 31,000; and the estimated crash rate was 6.0 crashes per million VMT.

M-85 Fort Road. The boulevard section extends from I-75, one mile south of the Wayne/Monroe County line northeasterly 14.6 miles to I-75 in the City of Detroit. A major improvement was made to this section in 1956. The improvement probably included added capacity, and it is likely that the indirect left turns were introduced at that time. 1988 daily traffic volumes ranged from 8,700 VPD at the southern terminus to 39,900 near the northern terminus in Detroit. The estimated crash rate approximated 3.8 crashes per million VMT.

US-12 Michigan Avenue. This boulevard section is 15 miles in length. It extends from the west Wayne County line to Greenfield Road in Dearborn. A major improvement was made in 1972 to this roadway, which may have involved converting it to a boulevard section with indirect left turn provisions. 1988 daily traffic volumes ranged from 12,800 vehicles per day at the western terminus to 49,600 at the eastern terminus (Data Drive). The estimated crash rate was 5.6 crashes per million VMT.

M-1 Woodward Avenue. The long boulevard extends from McNichols Road in the City of Detroit in Wayne County to South Boulevard in the City of Pontiac in Oakland County. It is approximately 16 miles in length. The last major improvement was made in 1969. There is some question as to whether indirect left turns were introduced at this time or earlier. 1998 average daily traffic volumes ranged from 19,800 to 79,900. The estimated crash rate was 3.4 crashes per million VMT.

US-24 Telegraph Road. This boulevard extends from Eureka Road in Taylor, Michigan (Wayne County) to Orchard Lake Road near Pontiac (Oakland County) - a distance of approximately 33 miles. A major improvement in 1959 probably included widening and providing indirect left turns. Telegraph Road has several freeway and arterial interchanges, but it also has many at-grade intersections with provisions for indirect left turns. 1988 average daily traffic volumes in Wayne County ranged from 18,300 VPD at its southern terminus (Eureka Road) to 75,800 at I-96. Average daily traffic volumes in Oakland County ranged from 56,600 at the Northern Orchard Lake terminus to 96,000 at about 12-Mile Road on the south. The estimated crash rates were 5.4 crashes per million VMT in Wayne County and 3.7 in Oakland County.

Oakland County

M-10 Northwestern Highway. This boulevard section extends about 4.0 miles from I-696 northwesterly to 14 Mile Road. A major improvement was made in 1963 probably included capacity improvements and indirect left turns. 1998 average daily traffic volumes ranged from about 74,900 to 148,600. The estimated crash rate was 5.6 crashes per million VMT.

M-59. This road has several sections of boulevard within Oakland County. In total there are approximately 7.5 miles of boulevard with indirect left turns beginning at the western county line and extending easterly to Porter Road. However, there is no indication when they may have been introduced. The last major road improvements were made in the early 1980's. 1998 average daily traffic volumes ranged from 24,500 to 31,500 VPD. The estimated crash rate was 1.2 crashes per million VMT.

M-5. A two-mile "boulevard" section of M-5 between 12 and 14 Mile Roads was open in 1999. It has a wide median with provisions for indirect left turns.

Several county roads in Oakland County also contain indirect left turn lanes. Wide-median boulevards include the following.

1. Long Lake Road from Coolidge Highway to Rochester Road. This 3-mile section has an ADT of 22,000 vehicles per day.
2. Crooks Road from Long Lake Road to Square Lake Road. This section is slightly over 1-mile in length and has an ADT of 30,000 VPD.
3. Big Beaver Road from Coolidge Highway to Dequindre Road. This section is 5 miles long and carries between 53,000 and 66,000 VPD.

Livernois Road - a narrow median boulevard has an ADT of 32,000 VPD. This section is about 1.25 miles long.

DESIGN FEATURES

The design concept for the Indirect Left Turn Strategy (sometimes called the "Michigan U") is shown in Figure 2. The key features include:

1. Two-phase signal operation at the major intersection where all left turns are prohibited.
2. Directional U-turn crossovers for left turns located about 660 feet on each side of the signalized intersection. These may be coordinated with side streets and are sometimes signalized. (The signalized left turn eliminates cross weaves into the opposing traffic).
3. Right turn lanes on the artery and cross street.
4. Left turn lanes in the median of the artery for the U-turn crossovers.
5. Coordination of signals in each direction of travel along the artery to ensure progression.
6. Minor cross street intersections that are unsignalized become two "T" intersections. Thus, there are no direct unsignalized crossings of the median.

The current design template for the indirect left turn was officially established with design guidelines adopted by MDOT's Traffic and Safety Division in December 1987. The actual construction of this design had occurred many years before then, but the guidelines were established to provide guidance to MDOT's Design Division for various right-of-way and/or cross street options. They contain the dimensions, spacings and operations that should be considered.

The required median width was based on field tests of various design vehicles. These led to the minimum designs for 'U' turns set forth in Figure 3. The directional crossovers require a 60-foot median to accommodate WB-50 trucks on a six-lane highway, or a 50-foot median on an 8-lane highway. If encroachment into an auxiliary right turn lane is allowed, the required median width could be reduced 10 feet.

The desired location of crossovers is 660’ ±100’ from the signalized intersection. Additional crossovers may be provided at 660-foot intervals in urban areas and 1320-foot intervals in rural areas.

In urban areas where major developments occur frequently, midblock back-to-back directional crossovers are sometimes constructed to service these developments and to minimize travel time. The spacing between these midblock crossovers is set at 150 feet (100-foot minimum).

A typical signing plan for left turn movements is shown in Figure 4. A series of directional signs are complemented by appropriately placed regulatory signs.

BENEFITS AND IMPACTS

The safety and traffic operational benefits of directional median crossovers have been well documented. The indirect left turn strategy results in lower accident rates, increased capacity, and less travel times.

Safety.

The overall safety effects of directional crossovers, and bi-directional crossovers as reported in a Michigan State University Study[(2)] are summarized in Table 2. Directional crossovers have one-third the accident rate of two-way left turn lanes and about two-thirds the rate of that for bi-directional crossovers.

Table 3 compares the accident rates by type of accident for “boulevard” designs (both directional and bi-directional crossovers) with those for two-way left turn lanes. The boulevard designs have lower crash rates for all types of crashes. The major accident reductions with boulevard designs involve driveway and head-on left turn crashes.

The accident reductions resulting from replacing four bi-directional (full) median openings on 0.43 miles of Grand River Avenue in Detroit, Michigan, with directional openings are shown in Figure 5. The average number of accidents per year from 1990 to 1995 were reduced from 32 to 13 -- about a 61-percent decline. Angle crashes were reduced by 96 percent, sideswipes by 61 percent, and rear-end accidents by 17 percent. Injury accidents decreased by 75 percent(1).

The safety benefits of directional versus bi-directional crossovers as a function of traffic signal density were analyzed for 123 segments of boulevard containing 226 miles of highway(2). The results, shown below, indicate that directional crossovers have increasingly lower crash rates (accidents per 100 million vehicle miles) as traffic signal density increases. For typical suburban conditions, with signal densities of one or more signals per mile, the crash rate for directional crossovers was about half of that for bi-directional crossovers.

Signals Per Mile	Completely Bi-directional	Completely Directional	Percent Difference
0	420	480	+14
>0 - 1<	533	339	-36
1 - 3	1,685	856	-49
>3	2,658	1,288	-52

Traffic Operations.

Operational benefits include increased capacity, reduced travel times and improved signal coordination. Even though all left-turning traffic must pass through the traffic signals twice, by prohibiting left turns at the intersection of two roads only two phases are required, and more green time can be given to the through traffic on both roads. Several studies have documented the capacity gains and delay reductions.

Capacity.

A study by Koepke and Levinson[3] found that the directional crossover design provides about 14 to 18 percent more capacity than the conventional dual left-turn lane designs. Table 4 summarizes the detailed analysis results. Results of a critical lane volume analyses, taking into account overlapping traffic movements, show reductions of about 7 to 17 percent in critical lane volumes, depending upon the number of arterial lanes (6 or 8) and the traffic mix; see Table 5.

A Michigan study[1] cited capacity gains of 20 to 50 percent as a result of prohibiting left turns at intersections and providing two-phase traffic signal operations. Reported level of service comparisons for four- and eight-lane boulevards, suggested a 20-percent capacity gain (Figure 6). This increase is consistent with that estimated by Koepke and Levinson[3].

A study by Stover[4] computed critical lane volumes for the intersection of two six-lane arterial roads. Using these volumes, analyses conducted for NCHRP 420 computed the effects of redirecting left turns. The various comparisons are summarized in Table 6. The provision of dual left-turn lanes on all approaches reduces critical lane volumes by 12 percent over just providing single left turn lanes, but still requires multi-phase traffic signal controls. The rerouting of left turns via directional crossovers and their prohibition at the main intersection reduces critical lane volumes by 17 percent.

Travel Times.

Simulation analyses performed by Michigan State University[(2)] addressed whether or not the delay savings for through and right turning traffic are offset by the extra travel times imposed on left-turning traffic. The TRAF NETSIM model was applied to a six-intersection network, with spacing of 1/2 mile for three basic conditions: (1) Direct left turns from a 5-lane section; (2) direct left turns from a “boulevard”; and (3) indirect left turns from the "boulevard". The simulations found that indirect left turns experience less delay than direct left turns and that overall travel time in the network is less whenever the major entry links have a 50% or more saturation. At 70% saturation, the average travel time in the network was reported at 4.5 minutes per vehicle for directional crossovers versus 6.0 minutes per vehicle for two-way left-turn lanes (33 versus 25 mph).

Thus, the greater distances traveled by left turn vehicles via indirect left turn crossovers are offset by the reduced intersection delay.

Traffic Signal Progression. Two-way signal progression is possible at all times of the day on sections of divided roadways with directional crossovers. This is because signals for both directions are needed only at major crossroads that are locted at the mile or half-mile points. Other signals can be added at directional crossovers on side of the roadway to provide gaps. Since they effect only one direction of travel these signals can easily fit into the direction’s progression.

SUCCESSFUL MEDIAN MODIFICATIONS PROJECT -- *CASE STUDY*

By

KRISTI M. SEBASTIAN, P.E.
Safety and Traffic Operations Engineer

Wisconsin Department of Transportation
Division of Districts, District 2 (Waukesha)

Presented for the 4th National Conference on Access Management

Wisconsin Dept. of Transportation
Division of Transportation Districts, Dist. 2
System Operations Group
2000 Pewaukee Road, Suite A
P.O. Box 798
Waukesha, Wisconsin 53187-0798

ABSTRACT

It is necessary to plan and create sufficient access and travel patterns as development occurs along the highway system. Operational or collision problems can occur when large developments have access only along the highway. Congestion and collision problems arise due to the conflicts between traffic entering and exiting the facility competing for gaps in highway traffic.

An operational and safety problem existed at a divided highway in an suburban area with several commercial development accesses located solely along the highway; no alternative access from the local street system existed. An improvement project was undertaken to address the safety and operational concerns. The project incorporated measures to separate major conflicting movements, increase left turn storage, and remove U-turns and left turns from the through traffic lane. In addition to highway changes, some driveway and site changes were necessary to ensure internal travel patterns conformed with access and operational changes.

A before and after study was conducted to evaluate the project's impact. The safety impact review revealed that this segment has decreased from 55 collisions for the two years before the project to only 12 collisions (78% decrease) for the two years after the project was complete. Furthermore, the congestion problems observed prior to the project were also addressed.

The median and driveway modification project addressed the specific mid-block collision problems it sought to correct without adversely affecting any other portion of the highway. This significant reduction in collisions demonstrates the safety benefit of access and operational changes. Median and access modifications measures can be used in reducing crashes and improving the operation of both the state highway and business properties along a highway.

INTRODUCTION

Maintaining a safe and efficient highway system hinges upon creating sufficient access and travel patterns for residential and commercial developments located along the highway. Operational or collision problems can occur when high traffic generators have access only along the highway with no alternate access. Traffic entering and exiting the facilities must find gaps in through highway traffic. Often, both ingress and egress conflicting moves cannot be accommodated at the same access point. Congestion and collision problems can arise due to the delay and difficulty exiting the facility because vehicles entering the driveway have the first opportunity to utilize the gaps in highway traffic.

Several operational and safety problems existed along a half-mile segment of a six-lane divided highway within the Wisconsin Department of Transportation, Southeastern Wisconsin jurisdiction. This segment of Highway 100, between the signalized intersections of Layton Avenue and Cold Spring Road, has a posted speed of 40 mph. The 30' wide median has raised curb and gutter with limited median openings (See Figure 1, Study Area Exhibit). The businesses directly along the highway are separate from the residential area. No other access existed to allow the business traffic to depart from a side road and utilize the signalized intersections for alternative access onto the highway. As a result, several collision and congestion problems occurred.

The operational and traffic problems must first be fully understood in order to determine appropriate improvement alternatives. The community and businesses requested a traffic signal to address collisions at one business driveway. This measure is not necessarily the best improvement to address the issues. First, crash data and operational issues were reviewed to determine the specific problems. Project objectives were then established for considering alternatives. This led to establishing study project objectives and selecting improvement measures. The before and after improvement crash data was evaluated to demonstrate project effectiveness. This report will also discuss techniques for improving operation and safety which were developed based on this project.

FIGURE 1 STH 100 STUDY AREA

STUDY INVESTIGATION

Data collection and analysis is imperative to understanding the problem and issues. Improvement measures at one median opening can affect the overall operation along the segment. To review the problem in a comprehensive manner, the entire half-mile segment would require study.

Volume data was collected to conduct a signal warrant study and capacity analysis. Distance measurements, collision diagrams, speed data, driveway locations, and internal circulation patterns were all evaluated during the investigation phase. Retrieval of the crash data and field observations revealed specific collision and congestion problems along this highway segment.

A collision diagram was prepared for the two years prior to the improvement project (See Report Appendix -- Figure 2, Before Project Collision Results – 1993 & 1994). The highway segment from the median south of Layton to Cold Spring Road, had 135 total crashes for the two year study period. This highway segment, which was counted in 1993, has an annual daily traffic count (AADT) of 28,980 vehicles. This highway crash rate of 1276 collisions per 100 million entering vehicle miles is over three times higher than the statewide average crash rate of 373. The injury crash rate of 444 injury collisions per 100 million entering vehicles was also significantly higher than the statewide average injury crash rate of 122. The signal analysis evaluation indicated that an additional signal at Armour Avenue would create poor progression and have an impact on travel speed and delay. The signal analysis evaluation indicated an additional signal at Armour Avenue would have poor progression, increase delay, and lower the average travel speed for through traffic along the highway.

A large number of collisions occurred at the Wal-mart entrance located across from Armour Avenue. These crashes involved through traffic and vehicles exiting the business. Traffic attempting to make a left turn to exit this business incur delay while waiting for both the entering traffic and through highway traffic. The high number of angle collisions here could be attributed to motorists pulling out into too small of a gap because they became impatient waiting to leave.

Motorists were also experiencing long backups due to traffic entering and exiting a cinema on the opposite side of the highway. Poor parking circulation and the close proximity of parking spaces to the driveway caused difficulties for traffic to enter and exit the lot. A large number of vehicles were exiting the lot at the same time motorists were coming for the next set of shows. Particularly on Friday and Saturday nights, traffic would queue along the highway waiting to enter the lot to park. Motorists would become impatient while stopped on the highway waiting to enter the first driveway. Some motorists would weave out of the right most lane into the middle lane to travel to the next driveway. This presented a potential side-swipe problem with full speed traffic traveling in the middle lane. Other customers would avoid the lot congestion by parking on the opposing side of the highway and walking across the highway. While the median does provide some refuge across this six-lane highway, the heavy traffic and 45 mph travel speed creates a serious safety concern for pedestrians.

In addition to the congestion and safety problems at these two businesses, rear-end crashes occurred near the signalized intersections at the median opening (See Figure 2, median opening reference numbers 1 and 2). These openings, typically called “pre-U-turn” openings, allow traffic to turn around since U-turns are not legal at signalized intersections per Wisconsin law. Several problems arise, particularly for traffic using this opening after traveling through the signalized intersection. Traffic does not expect a motorists to stop in the through lane directly after receiving a green light to continue traveling along the highway. The left turn storage needs at the Layton Ave. signal precluded establishing a left turn or deceleration lane at these nearby median openings. In addition, motorists making left turns through a “courtesy gap” in traffic queued for the traffic signal result in additional right-angle collisions.

A signal analysis and warrant study was conducted for the Wal-mart main entrance and Armour Avenue (See Figure 2, median opening reference number 3). While this is a four leg intersection, the west approach has very little traffic. Most motorists use alternate roadways to access the subdivision in order to avoid the conflicts and congestion caused by the high traffic generated by the business driveway on the opposing side of the highway. The major volumes came from the Wal-Mart entrance that serves customer traffic, not a through travel need. Signalizing this entrance, which was only 900 feet from the Layton Avenue signal, would not allow good progression. Through traffic would experience more delay and lower average travel speeds. Additional stops for main highway traffic increases the likelihood of rear end collisions. Since U-turns are illegal at signalized intersections, traffic that currently utilizes this opening to make U-turns would be redirected. A major portion of cinema traffic made U-turns at this median opening to go north after leaving the lot. This site is the only median opening with a deceleration lane before the signal. The installation of a signal here would create indirection and the potential for moving safety and operational problems further down the highway. Based on these numerous issues and disadvantages, installing traffic signals was determined not to be the correct solution to addressing safety problems at this intersection. Furthermore, signals would not address the other collision and congestion issues along this highway segment.

To develop an improvement plan which will address the safety and operational problems for the study area, a set of parameters or goals must be outlined. Each alternative needs to meet the study objectives. The alternatives can then be taken to the community and businesses to discuss the plan and impacts.

PROJECT SCOPE

To address the safety and operational concerns, specific project objectives or goals were established. These objectives allowed various alternatives to be developed and evaluated. The specific elements of the project include:

- **Separate conflicting maneuvers to facilitate safe ingress/egress to businesses on the highway.** This allows the exiting traffic to utilize all available gaps in through traffic without first waiting for the traffic turning into the driveway. This measure reduces delay for traffic leaving the site. In addition, the median opening will no longer become congested with various vehicles turning onto and off of the highway.
- **Increase left turn storage lengths at signalized intersection, as needed.** Sufficient left turn storage is needed to accommodate the traffic volume turning at the signal. If the lane is too short, vehicles will spill back into the through lane, causing a safety and operational problem. The lane may also need to be lengthened to allow left turn traffic to get into the lane without being blocked by through traffic already queued at the traffic signal.
- **Prevent left turns from occurring at locations where opposing through traffic queues for the traffic signal (requiring turning through "courtesy" gaps).** This main crash problem is avoided by allowing only left turn maneuvers at an opening past the opposing through traffic queue.
- **Remove U-turns and left turns from the through traffic lane.** Installing a left turn deceleration and storage area provides refuge for turning movements, thus reducing rear-end crashes. Interruption in through traffic flow is also reduced since the lane eliminates the

need for through traffic to suddenly stop or move to the middle lane to avoid a stopped vehicle in the through lane.

Various median configurations and traffic flow pattern alternatives were investigated. Each alternative met the project objectives, but created different ingress/egress traffic flow patterns for the area businesses. Discussing the alternatives with the businesses and community was key in understanding travel patterns and determining which configuration would best meet their need. By reviewing the overall operation and discussing concerns with the community, alternatives were refined and a final median modification plan was chosen. These partnerships were critical to creating a plan that would address both the highway and business operation needs.

PROJECT IMPROVEMENT – MEDIAN MODIFICATION PLAN

The project's main objective was to incorporate measures to separate major conflicting movements. By separating conflicting movements, motorists are able to better utilize gaps to enter or exit the highway. In addition, improvements involved increasing left turn storage at signalized intersections as needed. The project closed median openings in order to prevent left turns from occurring at locations where opposing through traffic queues for the traffic signal (requiring turning through "courtesy" gaps). Refuge areas were incorporated to remove U-turns and left turns from occurring in the through traffic lane.

The project consisted of median modifications and internal lot changes (See Report Appendix -- Figure 3, STH 100 Median Modification Plan). The changes are broken into six separate modifications which address specific safety and operational problems.

1) **Pre-U-turn opening south of Layton Avenue …** Signs restricting left turns and U-turns were installed for southbound traffic to address left turn collisions involving a vehicle turning through a gap in traffic being struck by a through vehicle in the right lane.

2) **Pre-U-turn opening north of Layton Avenue …** Close the median to address the rear end and angle collision issues. Additional storage for southbound left turns was required for southbound left turns at the signal. A new directional southbound left turn opening was created to allow access to businesses on the east side of the highway. This new directional opening has a deceleration lane to remove turns from the through lane.

3) **Existing opening at Armour Avenue and Wal-mart's south driveway …** To address the angle collision problem and delay issues, traffic was restricted from existing. This change was accomplished through internal signing changes in the Wal-mart parking lot.
4) **Wal-mart's existing north driveway …** Create a new median opening to allow traffic to exit the Wal-mart and Cinema lots. The Budget Cinema driveway was relocated to allow traffic to turn left directly from the south lot. Signs were installed on STH 100 to prohibit the conflicting mainline left turns from occurring.
5) **Existing median opening at the northerly Cinema drive and Goodyear business …** The Cinema lot was modified to restrict exiting traffic from using this driveway. A deceleration area was created to remove southbound traffic from turning from the through lane.
6) **Pre-U-turn south of Cold Spring Road …** This opening was relocated to separate the traffic turning at Cold Spring Road from left turn and U-turn traffic traveling to or from businesses along the highway. The new median opening includes a deceleration area so

turning traffic is separate from through traffic.

In addition to highway changes, some driveway and parking lot changes were necessary so that the site configurations of the businesses work with access and operational changes. These changes included:

- Several businesses have relocated/shared driveways to allow access to new median opening locations. Specifically, the McDonald's and corner business share a relocated driveway aligned with a new directional opening which allows patrons to enter these businesses from the north. The businesses near Cold Spring also share a new driveway adjacent to the relocated median opening with deceleration area. A cross access driveway for the strip mall north of the Wal-mart was added to the allow these businesses to access the median opening at the Wal-mart's north driveway.
- The Budget Cinema created a new roadway behind the building to facilitate travel to the entrance and exit only driveways. Signing and lot changes were also performed by the business to accommodate relocating the southerly driveway.
- The Wal-mart added signs and pavement marking to create a traffic pattern through their lot to facilitate the new entrance and exit only driveways.

The chosen alternative resulted in operational changes to the median and businesses to address the actual problems along the highway segment. To determine the success of the project, the collisions for the two years after the project were prepared to compare with the collision data prior to improvement project. A traveling speed study was also conducted to allow for comparison of before and after project data.

PROJECT IMPROVEMENT EVALUATION

Collision comparison

The number of collisions which occurred within the study area before (1993-1994) and after the project (1996-1997) were compared. The 1996-1997 collisions diagram demonstrates the specific location and type of crashes which occurred after the improvement project (See Report Appendix -- Figure 4, Median Modification Project; After Project Collision Results). Collision data was collected for the entire segment including the two signalized intersections of Layton Avenue and Cold Spring Road. Traffic volume data is collected on a three-year cycle. These intersections were included to ensure the mid-block median project did not merely shift the collision problem. This project segment had an Annual Average Daily Traffic (AADT) of 28,980 in 1993 and an AADT of 24,900 in 1996. The traffic volume data was used to compute collision rates (number of crashes per 100 million entering vehicles) which compares the number of crashes with respect to the traffic volume for the highway.

Table I. Before and After Collision Data for STH 100 from Layton Avenue to Cold Spring Road

	Before Project				After Project				Reduction in Total Crashes (before vs. after)
	1993		1994		1996		1997		
Location Description	Total	Injury	Total	Injury	Total	Injury	Total	Injury	
Cold Spring Road	8	2	8	3	11	7	6	2	
Between Cold Spring & Armour	4	0	13	4	1	1	4	0	
Armour Drive	16	9	13	2	2	1	2	0	
Between Armour & Layton	6	4	3	2	0	0	3	0	
Layton Ave.	30	14	20	3	14	9	8	3	
S. of Layton	6	1	8	3	4	1	6	1	
Total: Entire Segment	70	30	65	17	32	19	29	6	54.81%
Total: Improvement Project Limits	26	13	29	8	3	2	9	0	78.18%

"Total" refers to the total number of collisions. "Injury" reports the number of injury collisions.

As Table I. demonstrates, the overall number of collisions from Layton to Cold Spring Road decreased by 55% after the project was complete. The crashes for this highway segment, excluding the intersections, decreased from 55 crashes for the two years before the project to only 12 crashes for the two years after the project was complete. This is a 78 % decrease in crashes.

Table II. Before and After Collision Rate Data for the Project Area and Statewide Average for Urban Highways

	Before Project				After Project				Reduction in Rate
	1993		1994		1996		1997		
Location Description	Collision Rate	Injury Rate	Collision Rate	Injury Rate	Collision Rate	Injury Rate	Collision Rate	Injury Rate	(before vs. after)
Total Collision Rate: Entire Segment	1324	567	1229	321	704	418	638	132	28.31%
Total Collision Rate: Improvement Project Limits	492	246	548	151	66	44	198	0	74.62%
Statewide Average	396	127	350	117	355	125	313	111	10.46%

Collision and Injury Rate is reported as the number of crashes per 100 million entering vehicle miles

Collision Rate for the project is based on an AADT of 28,980 for 1993/1994 and an AADT of 24,900 for 1996/1997

The crash rate for this segment prior to the improvement project, was well above the statewide average for similar highway segments (Refer to Table II., above). The after data indicates the crash rate for the entire segment was still above the statewide average. However, the specific improvement area, excluding the signalized intersections on each end of the project, had a total rate and injury rate well below the statewide average. Overall, the collision rate for the project limits was 74.62% lower than the collision rate prior to the project. The after data also shows the total number of injury crashes and injury crash rate both dropped significantly.

Travel Speed Comparison

A traveling speed study was conducted in 1993. Data was collected for the AM peak (7-8 AM), Mid day (10-11 AM) and PM peak (5-6 PM) time periods. The study showed motorists traveled at the posted speed or above. The study involved a test vehicle traveling along the highway with the platoon of vehicles. The study area included a two-mile segment of STH 100 to allow for the test vehicle to observe the travel speed at mid-block points and stopping/starting patterns at traffic signals for the corridor. The speeds were recorded outside of the project limits and at Armour Avenue. The results of the travel speed for the mid-block point within the study limits is shown in Table III below.

Table III. Before and After Travel Speed Data for STH 100 from Layton to Cold Spring Road

	Before Project		After Project		Difference
Time Frame	Northbound	Southbound	Northbound	Southbound	NB/SB
AM Peak	40.8	44.7	42	45.5	+1.2/ + 0.8
Mid Day	42.2	43	44.3	42.75	+2.1/ -.25
PM Peak	39.9	41	42.4	44.4	+2.5/ + 3.4

Traffic Data collected in traveling speed studies conducted September, 1993 and April, 2000.
Travel Speed was recorded at Armour Avenue.

Travel speeds actually increased within the project limits and the mid-block locations beyond the study area for most time periods. Since the travel speeds increased throughout the two-mile study segment and not just within the half mile project segment, the project improvement is not likely to be the reason for the speed change. It can be concluded that the median change did not adversely affect the travel speed for this area.

CONCLUSIONS

The median modification project addressed the specific mid-block collision problems it sought to correct without adversely affecting any other portion of this highway segment. This significant reduction in collisions demonstrates the safety benefit of this project. Additionally, the travel speed was not reduced nor did the Department received complaints of operational problems with traffic entering/exiting businesses along STH 100. One minor modification was made after the project which clarified the operation of the directional left turn lane at the McDonald's restaurant (Refer to Figure 3, median site number 2). In summary, closing median openings to prohibit turns through traffic queues, separating conflicting turn movements, and providing deceleration areas for turning motorists outside the through lane are effective measures in reducing crashes and improving operation of the state highway and business properties along the corridor.

While the project was successful, retrofitting modifications to address existing problems is not ideal. Ultimately, planning access to minimize conflicts must be considered when working with development requests. To prevent problems when planning new developments, alternate access to the main intersections is necessary to direct high volume turn movements to the existing traffic signals. This minimizes conflicts at non-signalized mid-block openings on the main highway. When new signals are necessary to accommodate large developments, the signal needs to be installed at locations which connect to an internal street system so motorists can enter and exit the highway without creating excessive delay for the through highway. To ensure safe turn maneuvers into businesses, a capacity analysis and field review are needed to determine length of queues at signals. Creating deceleration refuge areas for left turns will minimize delay and the possibility of rear-end crashes. Checking existing and projected gaps will determine if the conflicting entering and existing traffic can be accommodated at the same non-signalized median opening. These steps ensure that developments are set up with good ingress/egress patterns and access points which will not incur excessive delay leading to safety concerns. Creating well planned access and internal operation will allow new businesses to operate along the highway while maintaining a safe and efficient highway system to serve new developments, existing businesses, and highway travel needs.

APPENDIX

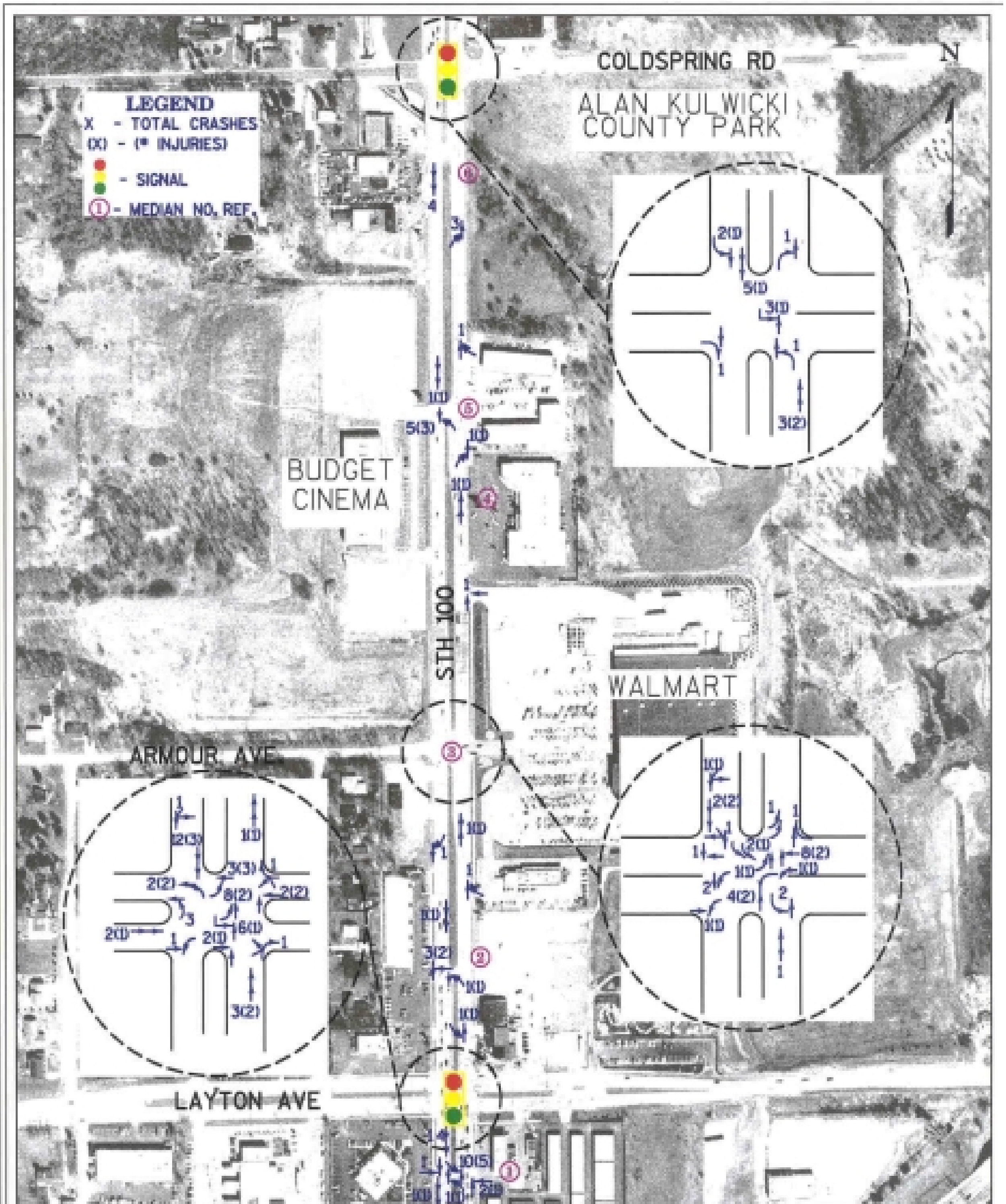


FIGURE 2 Median Modification Project; Before Project Collision Results - 1993 & 1994

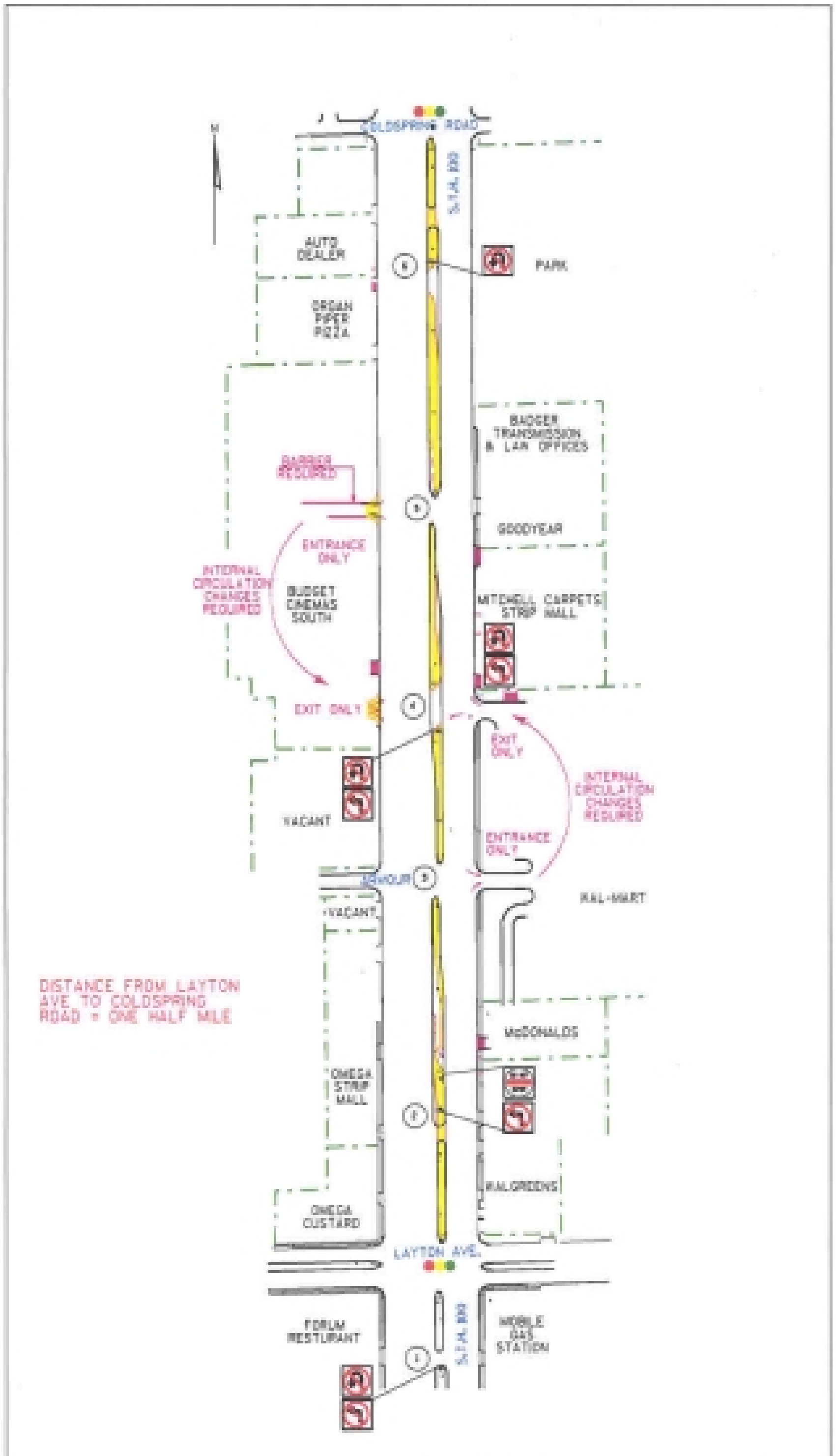


FIGURE 3 **STH 100 Median Modification Plan**

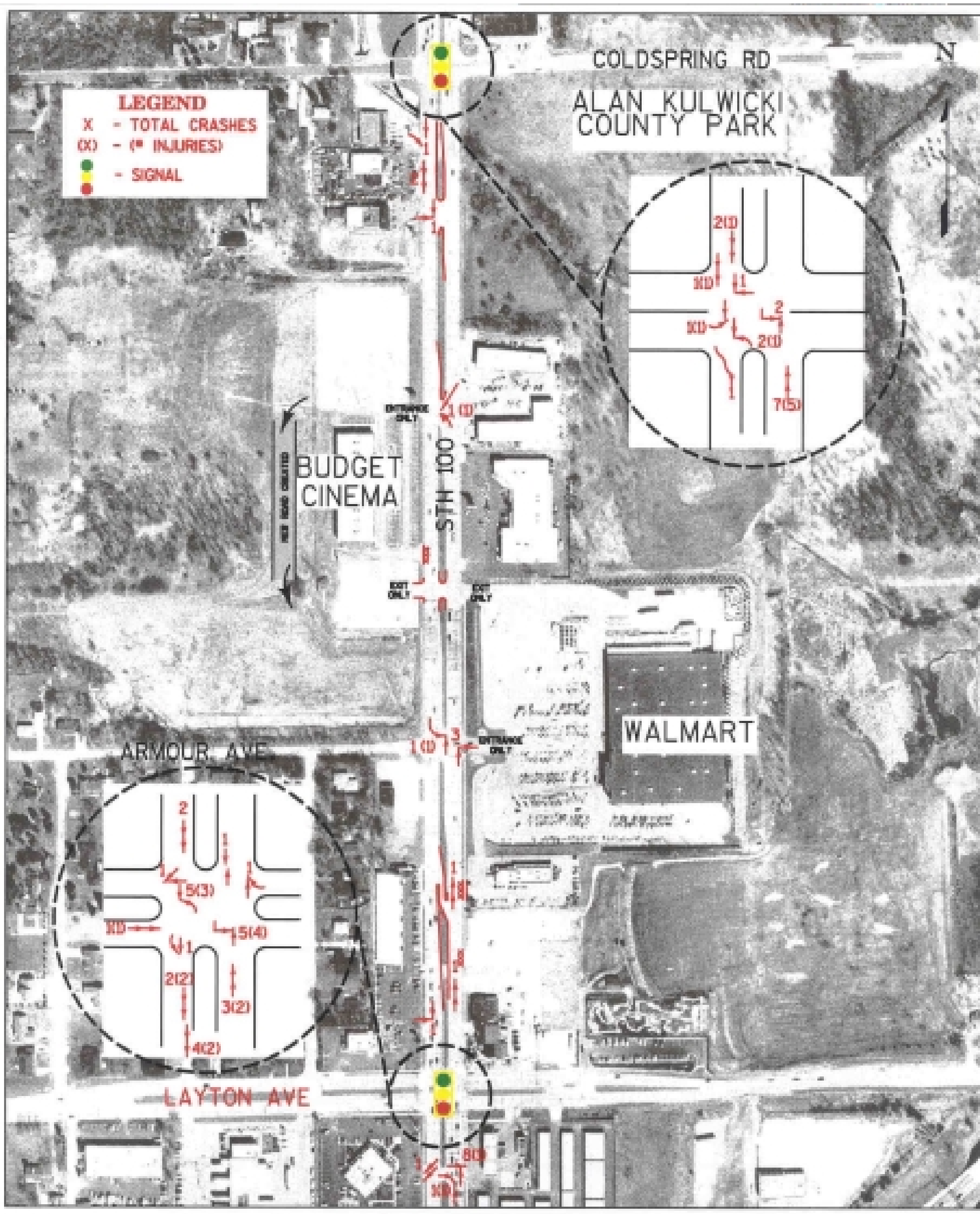
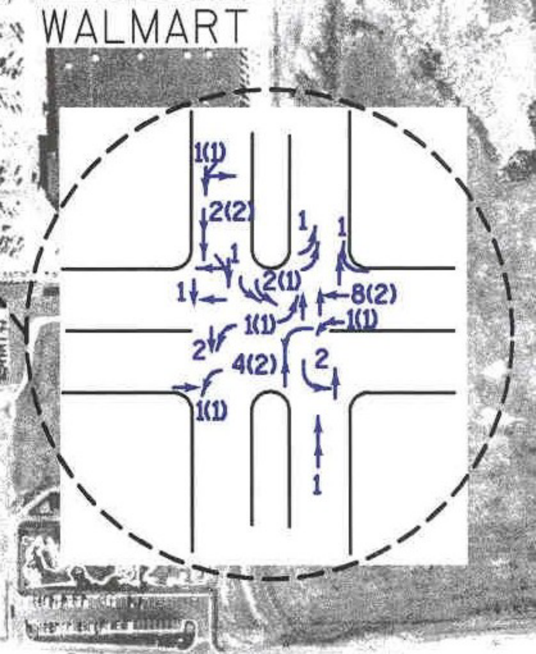


FIGURE 4 Median Modification Project; After Project Collision Results - 1996 & 1997


STH100N MILW40 940606 182334
A26579
30-03.4+4.2.03 -0.1


WALMART
1(1)
2(2)
1
1
1
1
2(1)
8(2)
1(1)
1(1)
2
4(2)
2
1(1)
1

GEORGIA STUDY CONFIRMS THE CONTINUING SAFETY ADVANTAGE OF RAISED MEDIANS OVER TWO-WAY LEFT-TURN LANES

by

Peter S. Parsonson
School of Civil & Environmental Engineering
Georgia Tech
Atlanta, Georgia 30332-0355
(404)966-2244
Fax: (404)894-2278
peter.parsonson@ce.gatech.edu

and

Marion G. Waters III
State Traffic Operations Engineer
Georgia Department of Transportation
Atlanta, Georgia 30334-1002
(404)656-5423
Fax: (404)635-8116

and

James S. Fincher
Transportation Engineer III
Georgia Department of Transportation
Atlanta, Georgia 30334-1002
(404)635-8132
Fax: (404)635-8116

April 7, 2000

Prepared for Presentation at the
Fourth National Conference on Access Management
Portland, Oregon
August 14, 2000

GEORGIA STUDY CONFIRMS THE CONTINUING SAFETY ADVANTAGE OF RAISED MEDIANS OVER TWO-WAY LEFT-TURN LANES

ABSTRACT

The Georgia DOT recently completed a large study of the crash statistics for all of the divided highways on the State Highway System for the period 1995 through 1998. The highway sections had either four or six through lanes and were classified by type of median into either a) TWLTL or b) a non-traversable center strip consisting of either a raised median with concrete curbing or else a depressed grass median and referred to simply as "raised median" or RM. It was found that the RM design is much safer than TWLTL. A striking result was that overall (intersections plus mid-block locations), RM had 78 percent fewer pedestrian fatalities per 100 miles of road, no doubt due to the relatively safe refuge area provided pedestrians by RM. A similar study performed six years earlier by the GDOT indicates that the safety gap between RM and TWLTL is widening with time. It may be that drivers increasingly distracted and inattentive to the driving task are increasingly in need of a more-structured and disciplined highway environment such as that provided by non-traversable medians.

INTRODUCTION

Since the mid-1980s the Georgia DOT has sponsored contract research (1) and performed in-house studies to determine the relative safety of two-way left-turn lanes and non-traversable medians. Gwinnett County, in metro Atlanta, took note of this and other research and by 1990 decided that, for safety, all new and reconstructed principal and major thoroughfares should be designed with raised medians; and existing arterials with two-way left-turn lanes should be considered for installation of a raised median if the projected growth in traffic reaches or exceeds 24,000 to 28,000 vehicles daily (2).

In 1990 the GDOT replaced a TWLTL with a raised-median separation along 4.34 miles of Memorial Drive in DeKalb County in metro Atlanta. In the year after completion, the project prevented about 300 crashes and 150 injuries (3). There was a 37 percent drop in total crash rate and a 48 percent drop in the injury rate. As would be expected, left-turn crashes between intersections were virtually eliminated.

The raised median caused reductions in crashes on Memorial Drive for the following reasons:

- Conflict points were reduced in number.
- Conflict areas were reduced in size.
- Pedestrians found refuge while crossing.
- Mid-block crashes dropped because of the elimination of left turns in and left turns out.
- Left turns were eliminated into and out of seven public roads and many driveways, as they were not given median crossovers (breaks in the raised median).

- All 14 median crossovers (at 10 major public-road intersections and four significant private driveways) were signalized. These are full openings, not channelized to allow only left turns or U turns.
- Intersection crashes dropped because of excellent design of geometrics, with double left-turn lanes and U-turn capabilities, and because seven intersections became right into and right out from the cross streets.

The GDOT has monitored the crash statistics on Memorial Drive since the 1990 retrofit. As of this writing in 2000, there has still not occurred the first fatality, either motorist or pedestrian, since the installation of the raised median. While the crash rate has increased during the decade, the increases have simply tracked the increases in number of crashes experienced by DeKalb County as a whole (4). That is, while the crash rate has increased during the 1990s, the benefit relative to the TWLTL design appears to have remained intact.

RECENT GEORGIA RESEARCH

The GDOT recently completed a study of the crash statistics for all of the divided highways on the State Highway System, urban and rural, for the period 1995 through 1998. The highway sections had either four or six through lanes and were classified by type of median into either TWLTL or Divided. The former indicates a flush-paved median consisting of a two-way left-turn lane, and the latter indicates a non-traversable median consisting of either a raised median with concrete curbing or else a depressed grass median. Both types of non-traversable median are hereinafter called “raised medians,” for compatibility with the literature on the topic.

The 986 sections of TWLTL studied totaled 839 miles, for an average section length of 0.85 miles. The sections varied widely in length from to 0.04 to 6.49 miles, except for one section that was over 83 miles long. The ADTs for 1997 were taken as representative and varied over a wide range from 1,200 to 68,100 vehicles per day, averaging 18,500 vpd. The daily vehicle-miles of travel (VMT) were calculated for each section by multiplying the ADT by the length; they averaged 15,725 vehicle-miles per day.

There were 1,125 sections of raised median studied, totaling 1,295 miles in length, for an average section length of 1.15 miles. The sections varied in length from 0.01 to 9.68 miles, except for one section that was 14.77 miles long. The ADTs in 1997 varied from 810 to 72,300 vehicles per day, averaging 13,900 vpd. The daily vehicle-miles of travel averaged 15,985, close to the value for the TWLTL sections.

The analysis obtained statistics for total crashes (meaning those at midblock as well as at intersections), and separately just for mid-block collisions. There was no separation of four-lane sections from six-lane sections, nor separation of urban from rural. Crash rates were calculated per 100 million vehicle-miles of travel, except that the exposure to pedestrian collisions was considered to be related more to the length of road than to the volume of vehicular traffic. Therefore, pedestrian fatalities were calculated per 100 miles of road.

RESULTS

Table 1 gives the statistics for total crashes. The table shows that raised medians had a crash rate 45 percent lower than that for the TWLTL sections, and had a 43 percent lower injury rate. The overall fatality rates for motorists and non-motorized travelers were comparable, but the rate of pedestrian fatalities was 78 percent lower for the raised-median sections.

TABLE 1. Total Crashes, Injuries and Fatalities on Georgia's Divided Highways, 1995-98

Median Type	Miles Studied	Avg. Veh. Per Day	Crash Rate†	Injury Rate†	Fatality Rate†	Pedestrian Fatalities Per 100 Miles
TWLTL	839	18,500	561	269	1.66	3.13
RM	1,295	13,900	310	153	1.59	0.69
Percent Difference, RM < TWLTL			-45	-43	-4	-78

Note: Total means including crashes at mid-block and at intersections
TWLTL means Two-Way Left-Turn Lane
RM is raised median, and includes depressed grass medians as operationally similar
† Rates are crashes per 100 million vehicle-miles of travel

Table 2 is similar to Table 1 but includes only mid-block crashes. The table shows that raised medians had a crash rate 45 percent lower than that for the TWLTL sections, and had a 48 percent lower injury rate. The overall fatality rates were 26 percent lower for the raised-median sections, and the rate of pedestrian fatalities was 78 percent lower for the raised-median sections.

TABLE 2. Mid-block Crashes, Injuries, Fatalities on Georgia's Divided Highways, 1995-98

Median Type	Miles Studied	Avg. Veh. Per Day	Crash Rate†	Injury Rate†	Fatality Rate†	Pedestrian Fatalities Per 100 Miles
TWLTL	839	18,500	173	82	0.90	1.82
RM	1,295	13,900	95	43	0.67	0.52
Percent Difference, RM < TWLTL			-45	-48	-26	-71

A comparison of the fatality rates in the tables indicates that raised medians effectively reduce total fatalities (motorists, pedestrians and bicyclists) at mid-block locations (Table 2). However, this advantage is essentially offset by the additional fatalities at intersections, resulting in little net advantage in the total fatality statistics shown in Table 1. This is understandable and points to the need for raised-median designs to include high-type intersection features such as double left-turn lanes and adequate radii for U-turns.

Perhaps the most striking statistics in the two tables are the reductions of over 70 percent in pedestrian fatalities afforded by raised medians. Two-way left-turn lanes have pedestrian fatality rates of 1.82 at mid-block and 3.13 at mid-block and intersections combined. Therefore, the rate at intersections must be 3.13 - 1.82 = 1.31, a value less than the mid-block rate. While pedestrians are supposed to cross at intersections, many are reluctant to bother to take the extra steps to reach an intersection. Moreover, many pedestrians sense the complexity of intersection crossings, and cross mid-block instead, increasing their risk (3). Raised medians provide a relatively safe refuge for pedestrians at both mid-block and intersection-crosswalk locations and are particularly vital to the safety of six-through-lane arterials where pedestrians are present.

COMPARISONS WITH A SIMILAR STUDY SIX YEARS EARLIER

The GDOT performed similar research for the four-year period 1989 through 1992 and obtained results comparable to those reported herein for the period 1995 through 1998. They are shown in Tables 3 and 4.

TABLE 3. Total Crashes, Injuries and Fatalities on Georgia's Divided Highways, 1989-92

Median Type	Miles Studied	Avg. Veh. Per Day	Crash Rate†	Injury Rate†	Fatality Rate†	Pedestrian Fatalities Per 100 Miles
TWLTL	584	17,923	623	256	2.16	3.64
RM	946	11,500	367	164	1.89	1.45
Percent Difference, RM < TWLTL			-36	-36	-13	-60

TABLE 4. Mid-block Crashes, Injuries, Fatalities on Georgia's Divided Highways, 1989-92

Median Type	Miles Studied	Avg. Veh. Per Day	Crash Rate†	Injury Rate†	Fatality Rate†	Pedestrian Fatalities Per 100 Miles
TWLTL	584	17,923	180	76	1.17	2.65
RM	946	11,500	105	47	0.84	0.82
Percent Difference, RM < TWLTL			-42	-38	-28	-69

A comparison of Tables 1 and 2 with their counterpart Tables 3 and 4 shows the following:

- Every measure of safety has improved over the six-year period, except that the injury rate for TWLTL has gone up a little.

- For the most part, safety is improving at a faster rate for raised-median sections, so the percent difference, RM<TWLTL, is increasing. That is, safety-wise there is a gap between RM and TWLTL that appears to be widening with time. The one exception is fatality rate, where TWLTL is improving at a faster rate than is RM, such that today they are almost tied.

CONCLUSIONS

Two large studies of the relative safety of two types of median treatments have been performed by the Georgia DOT since 1989. Each included four years of data and comprised very large road mileages, such that the derived data are sure to be very stable and significant statistically. Both studies showed that raised medians (and depressed grass medians) are much safer than two-way left-turn lanes, and there is evidence that the safety gap is widening with time.

While human factors are not discussed in this paper, there is no doubt that driver distraction and inattention are an increasingly important factor in crash causation, as pointed out in Reference 4. It could well be that driver preoccupation with cell phones and many other concerns unrelated to the driving task will necessitate a more structured and disciplined highway environment, including not only non-traversable medians but also more-conservative operational measures such as protected-only left-turn phasing and consistent use of red clearance intervals at signalized intersections. These changes to the highway environment may be recommended and accepted for the purpose of meeting the needs of older drivers, but in reality are as much needed by the distracted younger driver.

The data presented herein are striking for their results regarding pedestrian fatalities. The data from 1989 through 1992 show that pedestrian fatalities per 100 miles were 69 percent less for raised medians at mid-block locations and 60 percent less overall. By 1995-1998 the respective figures were 71 and 78 percent. All four rates describing pedestrian fatalities dropped sharply in the six-year gap between studies, meaning that both TWLTL and raised medians are currently experiencing lower rates both mid-block and overall than they did earlier. However, raised medians overall are experiencing 78 percent fewer pedestrian fatalities per 100 miles than TWLTL, a result that argues strongly for the provision of this relatively safe refuge in the middle of our arterials.

REFERENCES

1. Squires, C.A. and Parsonson, P.S., "Accident Comparison of Raised Median and Two-Way Left-Turn Lane Median Treatments," *Record 1239*, Transportation Research Board, Washington, D.C., 1989, pp. 30-40.

2. Bretherton, W.M., Jr., Womble, J. E., Parsonson, P.S. and Black, G.W., Jr., "One Suburban County's Policy for Selecting Median Treatments for Arterials," *Compendium of Technical Papers*, Institute of Transportation Engineers 60th Annual Meeting, Orlando, Florida, August 5-8, 1990, pp. 197-201.

3. Parsonson, P. S., Waters, M. and Fincher, J. S., "Effect on Safety of Replacing An Arterial Two-Way Left-Turn Lane with a Raised Median," published in the *Proceedings* of the First National Access Management Conference, Vail, Colorado, August, 1993, pp. 265-270. Dr. Parsonson also presented an update titled "Medians vs. Two-Way Left-Turn Lanes: The Georgia Experience," at a numbered session of the Transportation Research Board's 75th Annual Meeting, January 9, 1996, Washington, D.C.

4. Parsonson, P.S., Waters, M. and Fincher, J.S., "Two-Way Left-Turn Lane With a Raised Median: Atlanta's Memorial Drive," presented at the Third National Conference on Access Management, Fort Lauderdale, Florida, October 4-7, 1998. Published in the Conference Proceedings pp. 133-140.

5. Florida Department of Transportation, Safety Office, "Florida Pedestrian Safety Plan," Tallahassee, 1992, p. I-9.

Operational Effects of a Right Turn Plus U-turn Treatment as an Alternative to a Direct Left Turn Movement from a Driveway

Huaguo Zhou, Jian John Lu, Nelson Castillo, Department of Civil and Environmental Engineering, and Kristine M. Williams, AICP, Center for Urban Transportation Research

University of South Florida, Tampa, Florida 33620

ABSTRACT

The Florida Department of Transportation (FDOT) restricts direct left-turn exits onto major arterials through median treatments, and provides for mid-block U-turns in advance of intersections in some areas to accommodate these movements. This research, sponsored by FDOT, evaluates the safety and operational effects of replacing direct left turns from a driveway with a right turn plus U-turn movement at varying distances from a driveway. Field experiments were performed to collect data at some typical sites. The average travel time, average waiting delay, speed reduction and conflict rate were used to measure the operational effects of replacing a direct left turn with right turn plus U-turn. Preliminary field data showed that the average waiting delay of the right turn plus U-turn movement is less than the average waiting delay of direct left turn movements. However, the total travel time of direct left turns was less than the right turn plus U-turn movement when the direct left turn volume was less than 50 vph or average queuing length was less than 3 vehicles per cycle of the upstream signal. Based on field data, it was found that there was a 1-2 mph speed difference between upstream and downstream of a full median opening. The conflict rate of the right turn plus U-turn was much less than that of the direct left turn. This paper reviews the preliminary results obtained from two test sites.

Key Words: Access Management, Traffic Operations, Traffic Conflicts, Travel Time, Speed Reduction, Delay, U-Turn Movement, and Direct Left Turn Movement.

INTRODUCTION

Florida prohibits direct left-turn exits onto major arterials in many locations through the use of nontraverseable medians, and provides mid-block median openings in advance of intersections in some areas to accommodate U-turn movements. When a full median opening was replaced by a directional median opening that only allows left-turn ingress to abutting developments, the left-turn egress movements would be made by turning right onto the arterial road and then making a U-turn downstream. Figure 1 illustrates the conflicting movements that occur with a direct left turn at full median openings and how the number of conflict points can be substantially reduced by replacing a direct left with a right turn plus U-turn. As shown in Figure 1, a right turn plus U-turn movement as an alternative to a direct left turn movement has the potential to significantly reduce traffic conflict points and improve safety. But few field data are available to substantiate this assumption. In addition, people often oppose being forced to make a right turn and U-turn due to the perception that it results in a longer travel time than a direct left turn. Hence, it is necessary to further evaluate the operational effects of these two movements, especially to compare the travel time and conflict rates.

Little documentation is available on the operational effects of providing U-turns as an alternative to direct left turns from a driveway. However, a few studies have analyzed the travel time effects associated with providing U-turns as an alternative to direct left turns. A study by Stover analyzed the operational issues associated with these two movements and established a procedure to calculate the delay in relation to upstream and downstream signal impacts using queuing analysis *(1)*. In NCHRP Report 420: *Impacts of Access Management Techniques*, an analytical model was developed and calibrated to estimate the travel time saving (or loss) in the suburban and rural environment where there are no nearby traffic lights *(2)*. The primary findings indicate that two stage left-turning vehicles will suffer longer delays than right-turning plus U-turning vehicles when the volumes on the major street are relatively high (i.e., more than 2,000 vph), and the left turns exceed 50 vph. As stated in NCHRP Report 420, this finding holds true even in cases where the right turn plus U-turn movement involves one-half mile of travel to the U-turn median opening *(2)*. A case study by Long and Helms showed that limiting access at unsignalized intersections can reduce turning volumes, increase arterial operating speeds, and improve safety *(3)*. A study by Al-Masaeid developed an empirical model to estimate the capacity and average total delay of U-turns at median openings *(4)*. There are some studies about travel time savings of the unconventional left-turn alternatives systemwide by computer simulation *(5,6)*.

This paper presents some preliminary results obtained from a research project sponsored by FDOT to evaluate the operational effects of replacing a direct left turn from a driveway with a right turn plus median U-turn alternative that is located at varying distances from a driveway. Field experiments were performed at two sites to collect traffic data. Total eighty-hour traffic data were collected at the two sites for the preliminary analysis. Traffic data (including average travel time and waiting delay, traffic conflict rate, and speed reduction due to direct left turning traffic or right turn plus U-turning traffic) were used to evaluate the operational effects of replacing a direct left turn with a right turn plus U-turn. Based on field data collected from the two sites, it was found that the average waiting delay of the right turn plus U-turn movement was significantly less than the average waiting delay of the direct left turn movement. From the preliminary study results, it appeared that there were certain speed reductions caused by traffic making direct left turns at a full median opening. Also, it showed that the speed reduction caused by vehicles making right turn plus U-turn movement at the weaving area was not significant. According the field data analysis, it was confirmed that the conflict rate caused by right turn plus U-turn traffic was much less than that caused by direct left turn traffic.

In the next phase of the research, several more sites will be selected and field experiments will be carried out at these sites to obtain more detailed results. It is anticipated that quantified procedures and approaches will be obtained from an analysis of several sites so that transportation agencies could use the procedures or approaches to assess the impacts of right turn plus U-turn treatments on traffic operations. The procedures or approaches could be used to determine whether or not to restrict direct left turn movements under certain traffic conditions.

MAIN DIFFERENCES BETWEEN THE TWO OPTIONS

Direct Left Turn

The main advantages of the direct left turn option include: (1) The delay and travel time could be less as compared to the right turn plus U-turn option under the low traffic volumes; and (2) Vehicles making direct left turns would travel less distance and may consume less gas as compared to the vehicles making right turn plus U-turns.

However, there are some concerns or disadvantages associated with the direct left turn option. These include: (1) Traffic delay and travel time may greatly increase under high traffic volume conditions; (2) Direct Left turn movements involve obtaining gaps in two directions at a time when the median is too narrow to safely store one vehicle; (3) This option results in more conflict points and vehicles making direct left turns have to yield to all other movements at a full median opening; (4) Capacity of direct left-turn movements is seriously limited by the median storage; and (5) Large trucks may block the through traffic when they are making direct left turns.

To evaluate the total travel time used by vehicles to make direct left turns, the total travel time can be defined by the following equation:

$$TT_L = t_{L1} + t_{L2} + t_{L3} \tag{1}$$

where:

TT_L - average total travel time of a direct left turn movement,
t_{L1} - average waiting delay of direct left turn vehicles at the driveway,
t_{L2} - average waiting delay of direct left turn vehicles at the median opening, and
t_{L3} - average running time for vehicles to leave the driveway to complete the left turn movement (not including t_{L1} and t_{L2}).

Total travel time can be used to evaluate the impacts of replacing direct left turn movements with right turn plus U-turn movements.

Right Turn Plus U-Turn

The main advantages of the right turn plus U-turn at a median opening include: (1) Travel time and delay could be less as compared with direct left turn movements under moderate and high traffic volume conditions; (2) The capacity of a U-turn movement at the U-turn median opening is much higher than the capacity of a direct Left turn movement at the left turn median opening; (3) A right turn plus U-turn movement create fewer conflict points; (4) Drivers would often make a right-turn plus U-turn movement in preference to a direct left turn under moderate to high traffic volume conditions; and (5) A U-turn median opening can be used to accommodate traffic from several upstream driveways, especially when the driveway spacing is very close.

Similar to the direct left turn option, the right turn plus U-turn option has some disadvantages. The main disadvantages include: (1) Waiting delay could be higher as compared with the direct left turn option if major road traffic volume is low; and (2) It takes longer travel distance and may consume more fuel as compared with the direct left turn option.

To estimate total travel time for vehicles making right turn plus U-turn movements, the following equation can be used:

$$TT_R = t_{R1} + t_{R2} + t_{R3} \qquad (2)$$

where:

TT_R - average total travel time of a right plus U-turn movement,
t_{R1} - average waiting delay of right turn plus U-turn vehicles at the driveway,
t_{R2} - average waiting delay of right turn plus U-turn vehicles at the U-turn median opening, and
t_{R3} - average running time for vehicles to leave the driveway to complete the left turn movement (not including t_{R2} and t_{R3}).

FIELD DATA COLLECTION

In this research, a study site was defined as an urban or suburban arterial street segment that has only two or more unsignalized access points along its length. The segment has a constant cross section and raised curb median. Geometric criteria of specific study sites are given as follows: (1) The site should have a raised-curb median with either a full median opening or directional median opening and median U-turn bay, where the medians can safely store waiting vehicles; (2) The site should have 6 or 8 through traffic lanes (3 or 4 lanes each direction). Passenger cars can normally make U-turns along divided a six-lane arterial; and (3) The site should have a speed limit of 40 mph or higher. The Florida DOT mandates that all multi-lane projects with design speeds of 40 mph or greater be designed with a restrictive median *(7).*

The results presented in this paper are based on data collected from two sites along Fowler Avenue in Tampa as listed in Table 1 and shown in Figure 1 and 2. At site one, the direct left-turn out from a driveway was replaced by a right-turn plus U-turn at a U-turn median opening with a weaving distance of 800 ft. At site two, there are three full median openings between the upstream and downstream intersections. Each can safely store two left-turning vehicles. The driveway at the second full median was selected to do the data collection because there are larger traffic volume making direct left turns and U-turns. At this site, drivers have two choices: either direct left turn or right turn followed by a U-turn at the next full median opening. To collect field data, video cameras were used to count conflicts and to monitor traffic operations between and around two median openings. Major traffic volume and speed were collected using the Automatic Traffic Counter (Peek ADR-100). A typical field setup is shown in Figure 4. Field experiments were conducted for two weeks at each site with four hours a day, including both peak and non-peak hours. About eighty hours of data were recorded by video camera at the two sites.

DATA REDUCTION

To compare the operational effects of these two movements, data from two field sites were reduced. While reducing the data, researchers tracked each vehicle, including both right-turn plus U-turn vehicles and direct left-turn vehicles. Four cameras and two traffic counters were set up at the same time so that time reference data from each of them could be matched. While reviewing the tapes, the following information was recorded: waiting delay of direct left turn vehicles and right turn plus U-turn vehicles at the driveway (defined as t_{L1} and t_{R1}, respectively), waiting delay of direct left turn vehicles at the full median opening and right turn plus U-turn vehicles at the U-turn opening (defined as t_{L2} and t_{R2}, respectively), running time of direct left turn vehicles and right turn plus U-turn vehicles (defined as t_{L3} and t_{R3}, respectively), major road traffic speed reduction caused by direct left turn vehicles and right turn plus U-turn vehicles, and traffic conflicts caused by direct left turn vehicles and right turn plus U-turn vehicles. All the average traffic data were based on a five-minute interval. Major road traffic volume and speed at different locations were recorded by the traffic counters with an average interval of five minutes.

DATA ANALYSIS

Effects on Travel Time

As defined previously, the total travel time to make a direct left turn or a right turn plus U-turn consists of average waiting delay at the driveway (t_1), average waiting delay at median openings for direct left turn movement or at the U-turn area for right turn plus U-turn movements (t_2), and average running time for both movements (t_3). From the two sites studied, traffic was recorded by four video cameras and travel time data were obtained by reviewing videotapes. Table 2 shows the comparison of the total travel time (t_1+t_2+t_3) and total waiting delay (t_1+t_2) of three types of movements: (1) two stage direct left turn, (2) right turn plus U-turn at full median opening, and (3) right turn plus U-turn at U-turn median openings. As shown in Table 2, the average total travel time for the direct left turn movement (45 sec.) was less than that for the two types of right turn plus U-turn movements (54 sec. and 52, respectively). The main reason for this was that the direct left turn volume was very low. In addition, the right turn plus U-turn traffic had to cross the weaving area. However, according to Table 2, the difference in total travel time was not significant. The average total waiting delay for the two types of right-turn plus U-turn movements (37 sec. and 31 sec., respectively) was less than that for the direct left turn movement (40 sec.). It is understood that the direct left-turn out traffic have to yield to the all other movements at the median openings in addition to through traffic. Thus, the left turn out traffic would take longer time at the driveway waiting until the median is clear to enter the median storage area as compared to the right turn traffic that would wait for only an acceptable gap of through traffic to merge the main road traffic. Therefore, the waiting time at driveway for direct left turn traffic (25 sec.) and right turn traffic (20 sec. and 18 sec., respectively) would be significantly different. It is much easier for the right turn traffic to departure from the driveway. Usually, the waiting delay has more impacts on the drivers' driving behavior. In fact, from field observations, it was noted that some drivers were waiting for gaps to make direct left turns. But, when the waiting time exceeded one minute or more or the queuing length exceeded three vehicles, these drivers changed their initial intention and looked for gaps to make right turn plus U-turns because they knew that it was easier and safer to a make right turn plus U-turn as compared direct left turns if the major road traffic and left-turn-in volume was heavy.

Speed Reduction

Right turn plus U-turn movements may have some impacts on major road traffic in the weaving area. One of the impacts could be speed reduction of the major road traffic. Major road traffic speed at upstream of the driveway may also be affected by direct left turn traffic from the driveway. To estimate the speed reduction of both right turn plus U-turn movements and direct left turn movements, the automatic traffic counters (Peek ADR-1000) were installed. One traffic counter was installed at the weaving area at both test sites to collect the speed data at 5 minute intervals. At site two, additional traffic counters were installed at 100 ft. downstream and 100 ft. upstream of the driveway to evaluate the speed reduction caused by the direct left traffic from the driveway.

Figure 4 shows that the average running speed of the major road traffic decreased slightly with the increase of right turn plus U-turn traffic volume for the peak hour and non-peak hour conditions in the daytime. An ANOVA statistical test was performed to test whether or not the right turn plus U-turn traffic volume had a significant impact on the speed. The test results indicated that the right-turn plus U-turn volume was not a significant factor at a 95 percent level of confidence.

At site two, the average speed of the upstream and downstream of the driveway was collected in pairs. Each pair of average speed at five minutes interval was taken under homogeneous conditions. To evaluate whether or not the average speed of the upstream and downstream of the driveway had a significant difference, the paired t-test was carried out. The test results indicated that at the 95 percent confident level the average speed at upstream (44.9 mph) was significantly lower than the downstream average speed (46.2 mph). The reasons for this could be the direct left turn traffic from the driveway and traffic making left turn into the driveway from the major road. The other reasons could be that the major road traffic making right turn into the driveway or making a left turn to the left turn bay might have some impacts on the speed of the major road through traffic. Figure 5 shows that the average speed of the major road through traffic at the upstream of the driveway was 1 to 2 mph slower than the average speed of the major road through traffic at the downstream of the driveway for the peak hour and non-peak hour conditions.

Traffic Conflicts

The traffic conflicts caused by right turn plus U-turn movements can be divided into the two parts: (1) conflicts between right turning vehicles and through vehicles, and (2) conflicts between U-turning vehicles and major road through traffic from another direction. The main conflict types are rear-end and sideswipe conflicts. The conflicts caused by direct left turn vehicles include the conflicts with two-direction major road through traffic and the conflicts with all other movements at the median opening for the driveway. The main conflict types include the angle and rear-end conflicts. In the research, traffic conflicts were recorded by video cameras in the fields. Conflict number was obtained by reviewing videotapes. While reviewing the videotape, three situations were used to judge if a conflict occurred: (1) brake light, (2) lane changing, or (3) perceptive deceleration. A total of 1975 right turn plus U-turn vehicles were tracked at site one. There were 56 conflicts occurred at weaving section between right turning vehicles and major road through traffic, and 43 conflicts between U-turning vehicles and major road through traffic. A total of 1764 direct left turning vehicles were tracked at site two. A total of 457 conflicts were counted from only camera one in the westbound. The conflict rates associated with the right turn plus U-turn vehicles and direct left turn vehicles from the driveway are presented in Table 3. For this study, conflict rates per vehicle observed was used to compare the difference of these two movements. The conflict data reveal that the conflict rates associated with the right turn plus U-turn vehicles (5.02 %) were much less than the conflict rates associated with the direct left turn vehicles (25.91 %). Most of the conflicts caused by the direct left turning vehicles were the conflicts with the left-turn-in vehicles. There were very few conflicts between the direct left turning vehicles from the driveway and the major road through vehicles. With the increasing of the waiting delay of the direct left turning vehicles, direct left turning drivers may tend to be more and more aggressive to move into the median opening without yielding to the left-turn-in vehicles from the major road.

CONCLUSIONS

As stated previous, the results presented in the paper are part of the results to be obtained through the research project. With these limited results, this paper intends to present the evaluation of the impacts of right-turn plus U-turn traffic from a driveway on the major road traffic. Much more test sites will be selected in the future and more details will be obtained from the data to be collected from the sites. In addition, the computer simulation software, CORSIM, will be used for more detailed simulation analysis.

REFERENCES

1. Vergil G. Stover, “Issues Relating to Weaving on At-Grade Roadways and the Right-Turn Followed by U-turn Maneuver, ” A Discussion Paper prepared for FDOT, 1994.

2. Jerome Gluck, Herbert S. Levinson, and Vergil G. Stover, *Impacts of Access Management Techniques, NCHRP Report 420*, Transportation Research Board, 1999.

3. Gary Long and Jeff Helms*, Median Design for Six-Lane Urban Roadways*, Transportation Research Center, University of Florida, October 1991.

4. Hashem R. Al-Masaeid, “Capacity of U-turn at Median Opening,” *ITE Journal*, June 1999.

5. Jonathan D. Reid, Parsons Brincherhoff, and Joseph E. Hummer, "Analyzing System Travel Time in Arterial Corridors with Unconventional Designs Using Microscopic Simulation", *Proceedings of the 78th TRB Annual Meeting*, Washington, D.C., 1999.

6. Joseph E. Hummer, "Unconventional Left-Turn Alternatives for Urban and Suburban Arterials-Part One," *ITE Journal*, September 1998.

7. Gary H. Sokolow, "Practical Considerations for Beginning a Comprehensive Access Management Program", *Proceedings of the First National Access Management Conference*, Vail, Colorado, 1993.

Table 1 Description of Field Sites

	SITE ONE	SITE TWO
Arterial	Fowler Ave.	Fowler Ave.
Location	N. 46th St.	19th St.
Speed limit	45 mph	50 mph
Weaving distance	800 ft	570 ft
Upstream green time(seconds)	108	100
Upstream red time(seconds)	17	70
Upstream signal cycle length(seconds)	125	170
Downstream green time(seconds)	105	90
Downstream red time(seconds)	20	80
Downstream cycle length(seconds)	125	170
Offset of upstream and downstream signal(seconds)	20	20

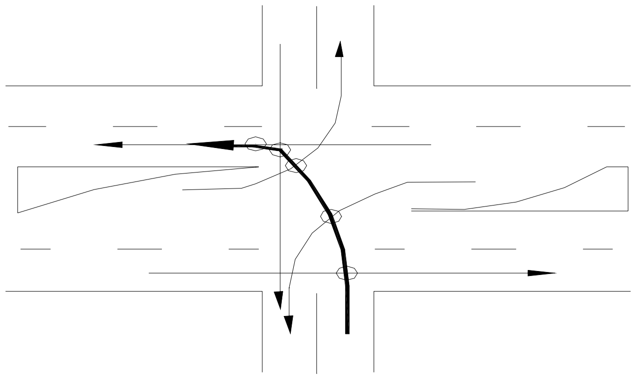


Figure 1.a Conflict Points of Direct Left Turns

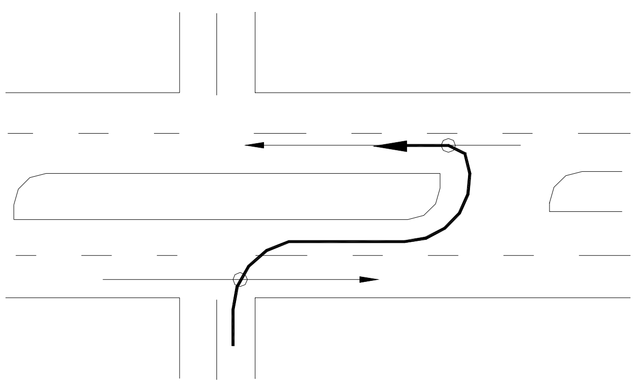


Figure 1.b Conflict Points of Right Turn Plus U-turn

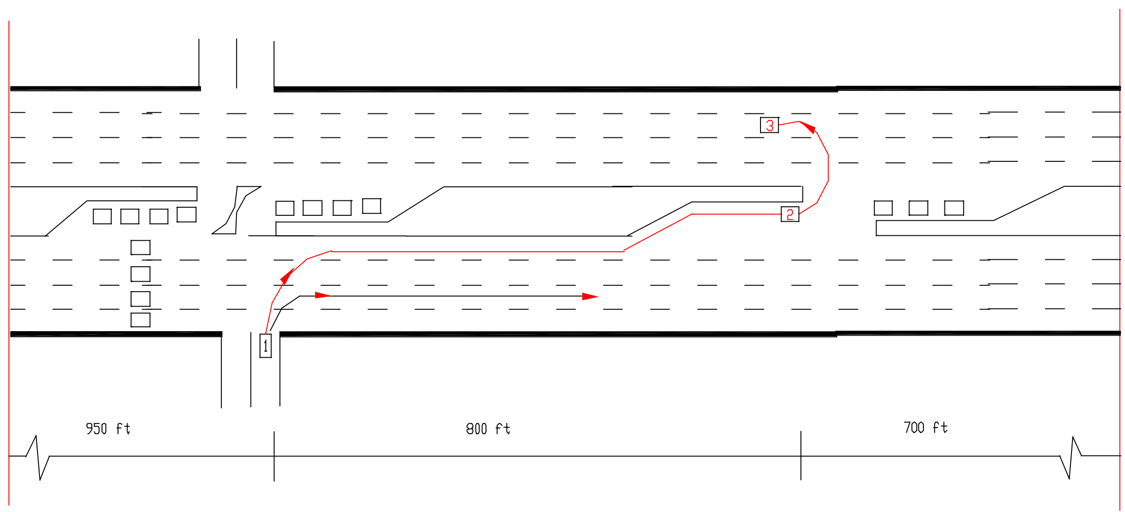


Figure 2: Vehicle Movements and Geometric Conditions of Site One

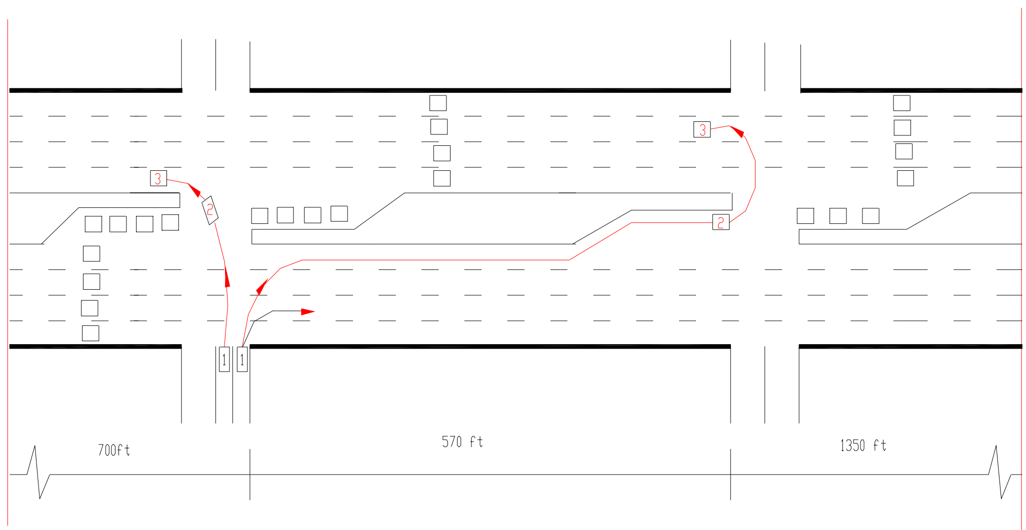


Figure 3: Vehicle Movement and Geometric Conditions of Site Two

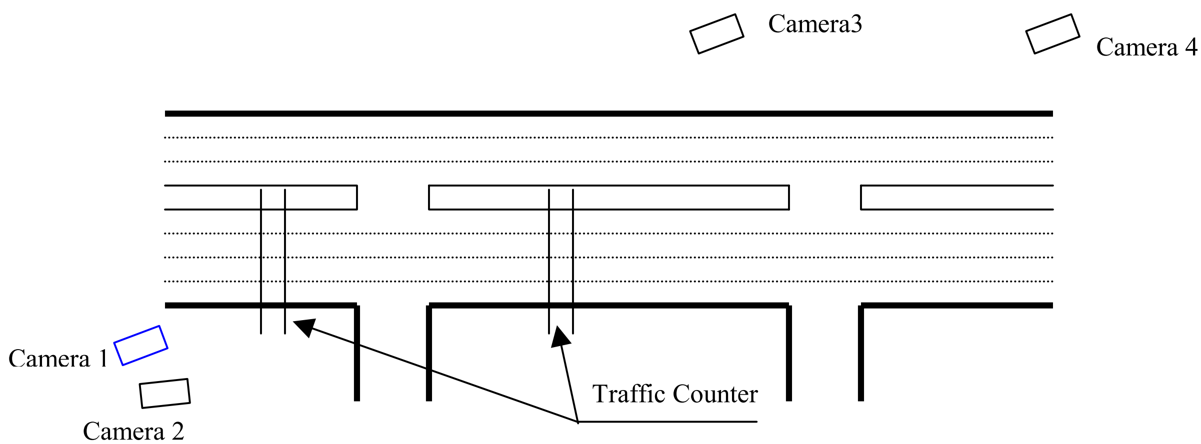


Figure 4: Typical Field Data Collection Setup

Table 2: Average Travel Time and Average Waiting Time

	DIRECT LT	RT+UT AT FULL MEDIAN OPENING	RT+UT AT U-TURN MEDIAN OPENING
Total conflicting volume (Range)	4600 (3000-6000)	4600 (3000-6000)	4400 (3000-5500)
Average LT volume (vph) (Range)	36 (0-96)	/	/
Average RT volume(vph) (Range)	/	208 (0-360)	190 (60-390)
Average U turn volume(vph) (Range)	/	84 (36-156)	47 (12-108)
Weaving distance (ft)	/	570	800
Average total travel time(seconds) ($t_1/t_2/t_3$)	45 (25/15/5)	54 (20/17/16)	52 (18/13/21)
Average waiting time(seconds)	**40**	**37**	**31**

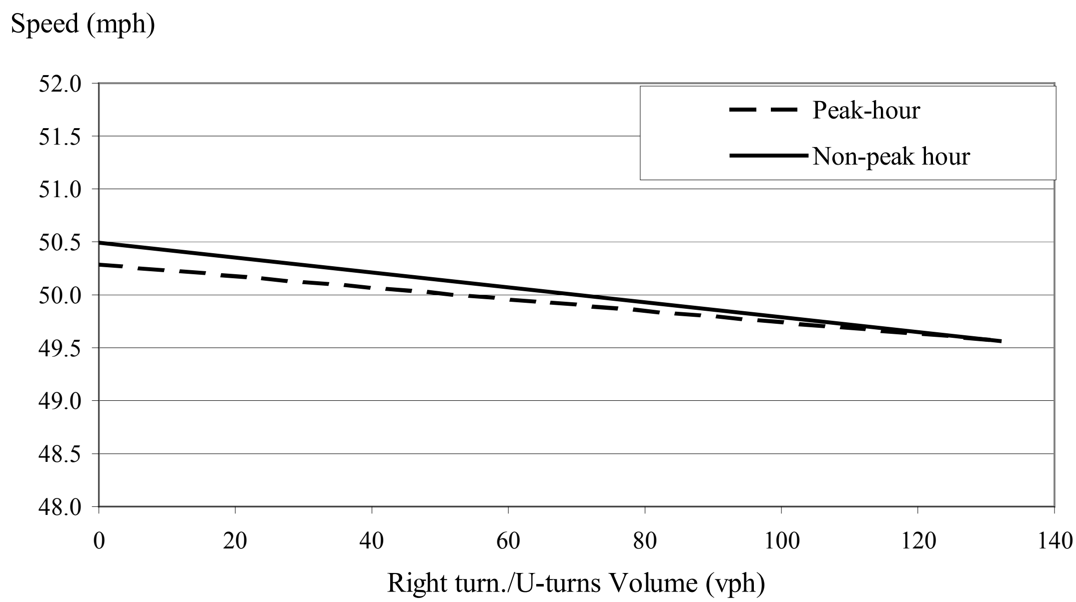


Figure 4: The Major Road Traffic Speed Reduction due to Right Turn Plus U-turn Movements at Weaving Section

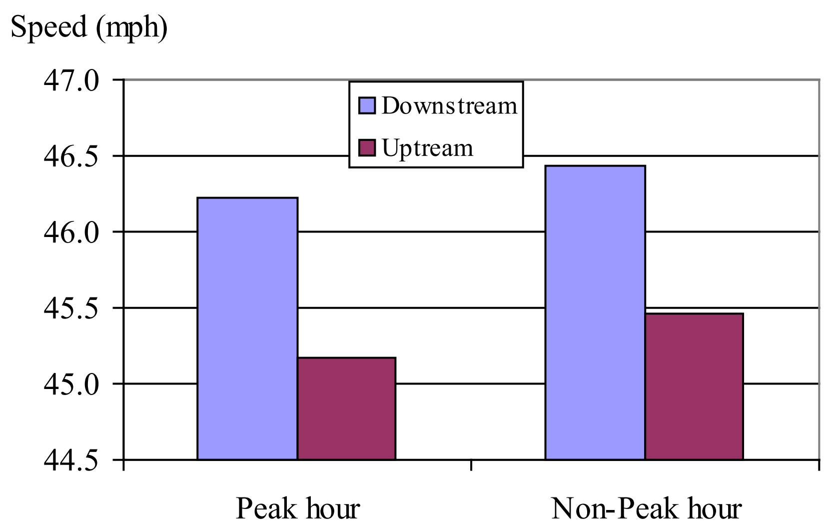


Figure 5: Average Running Speed of Major Road Traffic at Upstream and Downstream of the Driveway at Site Two

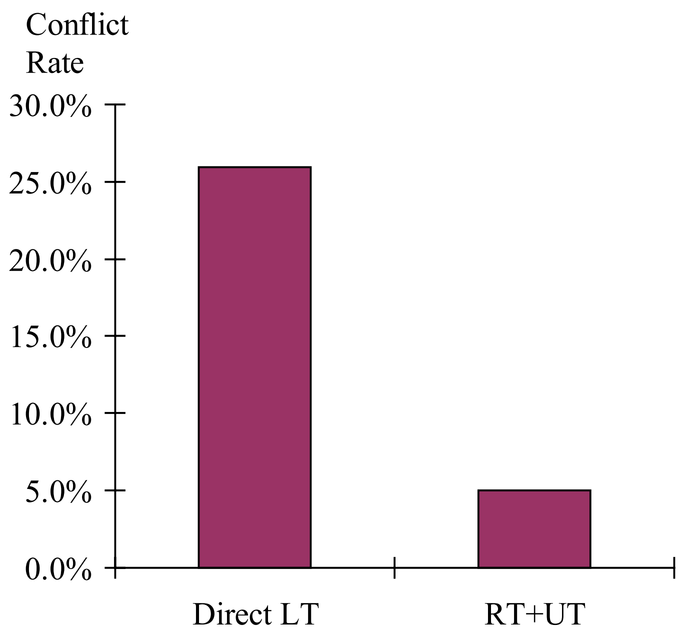


Figure 6: Comparison of Conflict Rates Caused by Direct Left Turn movements And Right Turn Plus U-turn Movements.

Table 4: Comparison of Conflict Rates

	Right turn plus U-turns		Direct left Turns
	Right turns	U-turns	
Number of Vehicles	1975	1975	1764
Number of Conflicts	56	43	457
Conflict Rates	2.84%	2.18%	**25.91%**
	5.02%		